TITLE

METHOD AND APPARATUS FOR MAKING BRISTLE SUBASSEMBLIES

CO-PENDING AND RELATED APPLICATIONS

This is a continuation-in-part of U.S. Serial No. 09/455,308, filed December 6, 1999 entitled "Bristle Subassemblies Having Parallel Pairs Of Bristles; And Methods Of Making Same" by Mark S. Edwards, which is a continuation-in-part of U.S. Serial No. 09/092,092, filed June 5, 1998 entitled "Method and Apparatus For Making Articles Having Bristles" by Mark S. Edwards. This application is related to co-pending application Serial No. 09/092,094, filed June 5, 1998 entitled "Monofilament Bristle Assemblies And Methods Of Making Brushes Using Same" by Mark S. Edwards; and Serial No. 09/550,657, filed April 17, 2000 entitled "Method And Apparatus For Making Bristle Subassemblies" by Mark S.Edwards (based on Provisional Application No. 60/130,883 filed April 23, 1999).

BACKGROUND OF THE INVENTION

Field Of The Invention

The present invention relates to a method and apparatus for making polymeric bristle subassemblies having a base string with polymeric monofilament bristles attached thereto and also to polymeric bristle subassemblies wherein two rows of polymeric monofilament bristles are attached to a single base string. The two rows are attached by passing a base string through a bristle bonding process at least twice in a "multi-pass" fashion.

Description Of The Related Art

The co-pending applications noted above describe a method and apparatus for making bristle subassemblies in which a monofilament is wrapped around a mandrel. There are two general variations of the apparatus. In the first variation, a base string is drawn along the outer surface of the mandrel so that the monofilament is wrapped in a transverse direction over the longitudinally disposed and translating base string. As the base string moves, it carries the "wraps" of monofilament under an ultrasonic horn which applies ultrasonic energy of sufficient quantity to cause the abutting surfaces of the base string and monofilament to heat and thus fuse together. After fusion together, the wraps are cut to thus form what are called "bristle subassemblies," which can be used to make a wide variety of articles, including bristles for brushes.

In this first variation of the apparatus, the wraps are transported to the ultrasonic horns by movement of the base string or strings. Typically, more than one base string is used on the mandrel. In the second variation, a cable is used to transport the wraps, and the base strings are brought into contact with the wraps outside the mandrel. An example of the second variation is illustrated in Figure 1.

Figure 1 shows a schematic view of a preferred embodiment of the second variation. In particular, filament 1 is fed from a spool (not shown) through a tensioning drive (not shown) and is continuously wrapped around a four-sided mandrel 5 by a wrapping mechanism 2 to form a plurality of continuous wraps 6 along the length of the mandrel 5. The wrapping

mechanism 2 is a high speed variant of the wrapping mechanism described in U.S. Patent No. 5,547,732, which is incorporated herein by reference.

A cable 4 made of metal wire or a suitable polymeric material runs down along groove 7a on the face of the mandrel and its direction is reversed by pulley 3a. The cable 4 then runs up the corner 7b of the mandrel 5 and moves the wraps 6 along the length of the mandrel. Cable 4 is redirected and runs down the back of the mandrel 5 in groove 7c and is redirected again by pulley 3b and runs up in the corner 7d of the mandrel to thereby support the wraps and move them along the length of the mandrel 5. An additional endless support cable (not shown) is synchronized with cable 4 and is positioned similarly on the two remaining opposite corners of the mandrel and runs in grooves on the opposite side of the mandrel 5. Pulleys (not shown) are required for the second endless cable to redirect and reverse the direction of the additional endless cable.

Base strings 8a, 8b, 8c, and 8d are fed through corresponding guide tubes 13a, 13b, 13c, and 13d to each side of the mandrel 5, preferably to each corner of the mandrel 5 as shown in Figure 1, and brought into contact with the wraps 6. Ultrasonic assemblies 9a, 9b, 9c, and 9d hold the base strings 8a-d in contact with the wrap 6 and provide sufficient energy to at least partially melt the base strings, the filaments of the wraps, or both, together. Typically, 0.1-1.0 joule energy is used to bond a thermoplastic polyamide monofilament base string to the filaments of the wrap.

As the filaments of the wraps are bonded with the base strings and proceed along the length of the mandrel 5, the filaments of the wrap are cut by cutters 10a and 10b into a plurality of bristle subassemblies 11a, 11b, 11c and 11d. Not shown are cutters on the opposite sides of the mandrel 5 positioned opposite cutters 10a and 10b. The bristle subassemblies 11a-d are then wound on spools and are available for use in making articles such as brushes, particularly toothbrushes.

The bristle subassemblies described above, after slitting, comprise a base string with two rows of monofilament bristles, with the bristles of each row somewhat angled to form a V-shape from an end view. The bristles of each row are integrally formed with corresponding bristles of the other row, due to the fact that the base string was bonded to the "wraps" at about a midpoint between two cuts imparted by the cutters.

Base strings used for the fabrication of tuft or bristle strings have historically been made with a single pass through the ultrasonic bonder, in the manner substantially described above (with the above-noted embodiment being directed to monofilaments rather than tufted filaments). This type of system limits the number of bristles or tufts per inch of a given bristle/tuft string and forms a single mix of bristles/tufts only.

SUMMARY OF THE INVENTION

The present invention includes methodology and an apparatus that uses a second bonder and wrapping head

in series with the first to create bristle/tuft strings which can have greater flexibility for use and manufacture. For example, a bristle/tuft string is first formed from first wraps bonded to a base string and slit or cut before passing over to a second wrapper and bonder system where another layer of tufts/bristles are attached. The second layer can either be attached to the same side or the opposite side as the first bristles/tufts. Thus, the population of bristles/tufts can be extended to twice the capacity of a single bonder; moreover, different sized and types of monofilaments can be easily combined, or monofilaments of different colors, shapes and other surface features can be combined to form bristles having a desired combination. The bristles can be partitioned in the bristle/tuft string, either layered on one side or on opposite sides of the base string.

If desired, and according to the present invention, additional bonder/wrapper assemblies can be placed in series to "build up" layers of bristles/tufts for specific applications or customer needs. By using two or more ultrasonic bonders and wrapper assemblies in series, bristle/tuft structures can be achieved that were not possible using the single pass wrapper/bonder mechanisms described in the related applications.

Single bonder/wrapper mechanisms can generate only one concentration of bristles per length of product, i.e., two red six mil filaments combined with one eight mil white. If desired, this product can have multiple layers each with its own unique formula of bristles, i.e., layer one comprised of two, red, six mil, round filaments mixed with one, six mil, round white; and

layer two comprises of two eight mil, blue, diamond-shaped filaments. Thus, the invention contemplates that a wide range of different shapes, colors, calipers, etc., can be formed either as layers on one side or opposite sides of the base string.

When making monofilament bristles, one particularly well suited polymeric material which forms the monofilament is nylon. These monofilaments have been used to make a wide variety of products, including brush bristles, fishing line, and tennis racket strings.

The present invention has several advantages. For example, high densities of large caliper bristles have a very narrow process window and are thus difficult to produce in a single pass. This is due to the combination of high stiffness of the multitude of wraps and high points where filaments have twisted and entangled. The multiple pass process reduces the count per wrapper/bonder to a range more suitable for high speed manufacture.

The features and advantages of the invention will become more apparent from the following detailed description when taken in conjunction with the illustrative embodiments in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic view showing a method and apparatus for forming bristle subassemblies using a single pass base string, in which the apparatus includes wrapping, bonding and cutting components;

Figure 2 is a schematic view showing a method and apparatus for forming bristle subassemblies using a multi-pass process, wherein at least two apparatuses for forming bristle subassemblies operate in series;

Figure 3 is a transverse, cross-sectional view of a mandrel according to the present invention, and showing in schematic form the location of the corner ultrasonic assemblies used to bond base strings to wraps at the corners of the mandrel;

Figure 4 is an enlarged view of the mandrel according to the present invention, and showing the features of the anvil and tip of the ultrasonic horn;

Figure 5 is a further enlarged view of one of the corners of the mandrel, and showing in detail the angle of the anvil under a wrap of monofilament;

Figure 6 is a cross-sectional view similar to Figure 3, showing the ultrasonic assemblies for the mid-point base strings;

Figure 7 is an enlarged view of a portion of the mandrel and ultrasonic assemblies of Figure 6;

Figure 8 is a further enlargement of a portion of the mandrel and ultrasonic assemblies of Figure 7;

Figure 9 is a transverse sectional view of the mandrel at the second bristle subassembly station, and showing the location of the ultrasonic assemblies for the corner base strings;

Figure 10 is an enlarged view of a portion of the mandrel and ultrasonic assemblies for the mandrel of Figure 9;

Figure 11 is a further enlargement of a portion of the mandrel and ultrasonic assemblies of Figure 9;

Figure 12 is a transverse sectional view of the mandrel at the second bristle subassembly station, and showing the location of the ultrasonic assemblies for the mid-point base strings;

Figure 13 is an enlarged view of a portion of the mandrel and ultrasonic assemblies for the mandrel of Figure 12;

Figure 14 is a further enlargement showing the contacting portions of the wraps and base strings of the mid-point base string;

Figure 15 is a transverse sectional view of the mandrel of the first bristle subassembly station, and showing the slitter assemblies;

Figure 16 is an enlarged view of a portion of the mandrel of Figure 15, with all slitters removed except one for the sake of illustration;

Figure 17 is an enlarged view of the mandrel of the second bristle subassembly station, showing a view similar to Figure 16 of a slitter at the mid-point base string, with other slitters removed for the sake of illustration;

Figure 17a is an enlarged view showing a corner slitter and cooperating bed knife or cutter bed;

Figure 18 is a schematic view of a conditioning apparatus for conditioning the cut ends of the bristles of the bristle subassemblies;

Figure 19 is an end view of the bristles of a bristle subassembly, showing the relatively jagged proximal ends at the base string, as seen in the broken line oval "A" of Figure 18;

Figure 20 is an end view of the bristles of a bristle subassembly, showing the proximal ends rounded

or smoothed following a conditioning step, as seen from the broken line oval "B" of Figure 18;

Figure 21 is an end view of the apparatus of Figure 18, showing the conditioning wheel extending into a cooling tank;

Figure 22 is a partial, enlarged view of the conditioning wheel of Figure 21, as seen from the broken line oval "C" of Figure 21;

Figure 23 is a schematic view of a conditioning apparatus according to another embodiment of the present invention;

Figure 24 is a partial end view of the conditioning apparatus of Figure 23, as seen along line D-D of Figure 23;

Figure 25 is an enlarged sectional view of the conditioning wheel of Figure 23, as seen from the broken line rectangle "E" of Figure 24;

Figure 26 is a transverse, cross-sectional view of a preferred base string, showing mid-point protrusions or ribs that improve control of the flow zone during the bonding process;

Figure 27 is an end view showing two subassemblies subjected to forces bring them in juxtaposition;

Figure 28 is an end view showing the two subassemblies of Figure 27 in a juxtaposed position and following application of ultrasonic energy, other heating source;

Figure 29 is a perspective view of an apparatus for forming modified subassemblies in which the starting materials are two subassemblies, each including a base string and a row of elongated members;

Figure 30 is an enlarged, partial end view showing the guiding grooves provided in the first and second guides of the apparatus of Figure 29;

Figure 31 is a partial cross sectional view showing a mandrel used for combining a first subassembly with additional wraps, and showing another embodiment of a knife bed according to the present invention;

Figure 32 is a view similar to Figure 31, showing the knife bed of Figure 31 used on a station used to make subassemblies;

Figure 33 is a side elevation view of a brush according to the present invention, in which the head portion is provided with an array of bristles formed by segments of the modified subassemblies of the present invention; and

Figure 34 is a front elevation view of the brush of Figure 33.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Figure 2, a multi-pass apparatus 20 for forming bristle subassemblies includes two bristle subassembly stations 22 and 24 which operate in series. In the first bristle subassembly station 22, a wrapping mechanism (not shown) wraps a monofilament around a mandrel 26 to form a plurality of wraps 28. The mandrel is provided with conveying cables (not shown) of the type described with reference to Figure 1, wherein the wraps are transported upwardly (from the view of Figure 2, since the wrapping mechanism would be located at the lower end of the mandrel) by rotation of the cables.

In the embodiment of Figure 2, eight base strings are fed to the wraps, four at the respective corners of the mandrel and four at the approximate mid-points between the corners. Preferably, all of the corner base strings are fed to the mandrel 26 at about the same vertical position along the mandrel. Of the four corner base strings, only two, 29 and 30, are shown in Figure 2. Each of the corner base strings 29 and 30 are fed from respective spools 32 and 34 and through respective guides 36 and 38. Again, from the view of Figure 2, only two of four guides, and two of four base strings and spools, are visible.

The guides position and hold the base strings as they pass under bonding means 40 and 42 which cause the base strings to bond and thus become connected to the wraps 28. Each guide has a respective bonding means 40 and 42, each of which is preferably an ultrasonic assembly. Each ultrasonic assembly includes a horn for delivering ultrasonic energy to the abutting wraps and base strings at one side thereof. On the opposite side, the mandrel provides an anvil so that the point where the wraps contact the base string is between the anvil and the horn. When energized, the horn delivers ultrasonic energy of sufficient magnitude to cause the base strings and abutting wraps to vibrate, thus generating heat at the interfacial surface of one or both the base string and wraps. As the bonded wraps and base strings are transported away from the ultrasonic assemblies, room temperature cooling occurs and the bond is complete.

At a vertical position spaced upwardly from the entry point of the corner base strings, the mid-point

base strings 44 and 46 are fed to the wraps on the mandrel from respective spools 48 and 50. The two other mid-point base strings and spools are not visible from the view of Figure 2. The base strings 44 and 46 are fed to the wraps of the mandrel through guides 52 and 54, respectively, which are juxtaposed respective bonding means or ultrasonic assemblies 56 and 58. These assemblies function the same as the other ultrasonic assemblies 40 and 42, and when operated, they cause the abutting surfaces of the wraps 28 to bond to the base strings 44 and 46.

Downstream of the ultrasonic assemblies 56 and 58, each face of the mandrel is provided with a pair of rotating cutter blades or slitters 60 and 62, making a total of eight slitters, which are positioned to cut the wraps 28 in close proximity to the bond point between the base strings and the wraps. As a result, eight bristle subassemblies 64,66, 68, 70, 72, 74,76, and 80 are formed. Referring to the enlarged section of bristle subassembly 76, each bristle subassembly includes a base string 82 and a plurality of bristles 84 connected to the base string at their proximal ends. The distal ends of the bristles terminate substantially in a common plane. The bristles themselves are formed after slitting the monofilament wraps 28 both at the proximal ends and distal ends.

A pair of drive rollers 86 and 88 take up the bristle subassemblies and feed them to the next bristle subassembly station 24. Although Figure 2 only illustrates two pairs of drive rollers, addition pairs may be employed to deliver the bristle subassemblies to the next processing station, or to a take-up spool.

Also, drive motors and control mechanisms are not illustrated for clarity, but any conventional drive means and control means can be employed.

The bristle subassembly station 24 includes structures very similar to the first station 22, such as a mandrel 90 around which is wrapped by a wrapping mechanism (not shown) a monofilament which forms a plurality of wraps 92. As in the first station, the second station 24 includes corner guides 94 (only one of which is illustrated) and corresponding ultrasonic assemblies 96, and mid-point guides 98 (of which only one is illustrated) and corresponding ultrasonic assemblies 100. As seen in the detail of the guide 94, the guide includes an upper part 102 and a lower part 104 which together define a slot which guides the base string 30 of the bristle subassembly 72 with the bristles 31 extending radially outwardly. In a similar fashion, the other bristle subassemblies are guided into juxtaposition with the wraps 92 so that the base strings 29, 30, 44, 46 and 82 (and the other three base strings not specifically illustrated in Figure 2) and attached bristles are fed to the second station 24.

After ultrasonically bonding the wraps 92 to the respective base strings at the second station 24, the cables (not shown in Figure 2) transport the bonded subassemblies to pairs of rotating cutter blades or slitters, including slitter pair 106 and 108. The slitters perform the same function as the slitters in the first station 22. In particular, the slitters are grouped in four pairs, two on each face of the mandrel, to cut the wraps 92 in close proximity to the respective base strings. The slitters cut the wraps

as they are transported by the slitters to form modified bristle subassemblies in which a second row of bristles 110 exist now on the side of the base string opposite the first row of bristles 84.

A pair of drive rollers 112 and 114, and other drive rollers as are necessary, are used to remove the modified bristle subassemblies and deliver them to take-up spools or to subsequent stations, where additional rows of bristles can be added to the existing row or rows of bristles. The speed of the drive rollers at each of the processing stations can be varied and controlled to ensure that bristle subassemblies are fed to the next station at a speed that allows further processing without excessive lag or tension.

Figure 3 is a cross-sectional view showing all four corner ultrasonic assemblies 40, 42, 43, and 45 of the mandrel 26 and corresponding removable insert 116, 118, 120, and 122. Each insert includes an anvil, which is in contact with the wraps 28 of monofilament. The anvils and corresponding distal ends of the ultrasonic horns of each ultrasonic assemblies engage the base strings and wraps to thereby deliver ultrasonic energy in an amount effective to induced localized heating of the base string and/or the wraps. A detailed view of two of the corners and associated structure is shown in Figure 4.

As seen in Figure 4, the inserts are mounted within cut-out regions of the mandrel 26, and can be held in place by use of any suitable means, including threaded fasteners, quick couplers, interference fitting, etc. The inserts 116, 118, 120, and 122 are

thus detachably coupled for ease of replacement. Each insert carries a corner anvil, which is best suited for the particular material of which the base string and/or wraps are made. Thus, depending on the combination of base string and wrap, the anvils may be formed in a variety of shapes and sizes to suit the particular base string. In the illustrated embodiment, the base strings, such as base strings 29 and 30, are square in section and made of a polymeric monofilament material, such as NYLON, or any other of the various materials that are described in the aforementioned related and/or co-pending applications.

In order to provide proper guidance and delivery of ultrasonic energy, the horns 40a and 42a of the ultrasonic assemblies 40 and 42, and those of the other ultrasonic assemblies, have a grooved end portion for receiving the corresponding base strings. For square section base strings, the groove is preferably rectangular in shape, and for circular section base strings, the groove has a curved shape of complementary radius. Base strings of different cross-sectional shape would preferably require similarly shaped grooves in the ultrasonic horn. The depth of the groove is generally no more than 70% of the base string thickness, and preferably less than 30%.

Anvil 116a has an upper surface over which the wraps 28 slide. Also, the upper surface provides the anvil surface impinging upon the wraps 28 which abut both the upper surface of the anvil and the base string 29 within the grooved end of the horn 40a. The anvil 116a further includes a groove on the side for slidably

receiving a transport cable 124, which transports the wraps 28 upwardly along the mandrel.

Similarly, anvil 122a has an upper surface over which the wraps 28 slide. Also, the upper surface provides the anvil surface impinging upon the wraps 28 which abut both the upper surface of the anvil and the base string 30 within the grooved end of the horn 42a. The anvil 122a further includes a groove on the side for slidably receiving a transport cable 126, which, together with transport cable 124 and similar transport cables at the other two corners, transports the wraps 28 upwardly along the mandrel 26. Since each transport cable represents an endless loop, the return path of each cable is accommodated in corresponding grooves 128 and 130.

As seen in Figure 4, the mid-point base strings 44, 46 and 132 have corresponding anvils 134, 136, and 138 which can be mounted on the inserts common to both the mid-point anvils and the corner anvils, or on separate inserts. In the illustrated embodiments, the corner anvils and the mid-point anvils are mounted on common inserts, two to an insert. In either event, the anvils are preferably removable since different anvils may be required for base strings and/or wraps of different size, type, and use. Moreover, the anvil is a wear surface, both with respect to the wraps and to the transfer cable, and thus, detachability is important to facilitate replacement of worn anvils.

As seen in the further enlarged view of Figure 5, the anvil 116a tapers gradually downwardly from the corner towards the mid-point of the corresponding mandrel face. Preferably, the angle of taper is about

0 to 5 degrees. This angle can be seen as the diverging gap between the inner surface of the wrap 28 and the upper surface of the anvil 116a. In any event, the surface characteristics, including the slope of the guiding portion of the upper surface, can be varied depending on the production speeds and type of materials used for the base strings and/or wraps. Also, the position of the ultrasonic assemblies does not necessarily have to be as illustrated, where the corner assemblies are at one position and the mid-point assemblies are at another.

Figure 6 is a cross-sectional view similar to Figure 3, showing the ultrasonic assemblies 56, 58, 140 and 142 for the mid-point base strings. In particular, the ultrasonic assemblies are positioned adjacent anvils 134, 136, 138, and 144. The anvils are detachably mounted on the inserts 116, 118, 120, and 122. Alternatively the anvils could be mounted on separate inserts; as a further alternative, all of the anvils could be detachably mounted in corresponding recesses formed in the mandrel. Finally, the anvils could be integrally, and permanently, formed on the mandrel. However, the fact that the anvils are removable is an advantage since different anvil geometry may be required depending on the type and size of the base strings and/or wraps that are being bonded. Also, the anvils are wear-surfaces and can be replaced as they wear out.

Figure 7 is an enlarged view of Figure 6, showing the base strings 44, 46 and 132 engaging the wrap 28 between the grooved ends of ultrasonic assemblies 56, 142 and 58, respectively, and the anvils 134, 136, and

138. It can be seen that the anvils make the wraps 28 kink slightly at about the mid-point between the corners of the mandrel, the angle of the kink corresponding to the taper angle of the anvil. As noted previously, the taper angle is preferably between 0 and 5 degrees.

The taper angle for each anvil can be seen in greater detail in Figure 8 with respect to base string 44. The base string is a polymeric monofilament of square section. From the view of Figure 8 the lower left corner of the base string 44 contacts the monofilament wrap 28 and the lower right hand corner of the monofilament is slightly spaced from the wrap 28. As a result, melting by application of ultrasonic energy is initiated at the lower left hand corner and progresses across the face of the base string. The lack of initial contact and indeed the spacing between the lower right hand corner of the base string and the upper surface of the wrap is dependent on the degree of taper in the anvil. The ideal degree of taper can be selected on a case-by-case analysis of what works best with which materials, shapes, sizes, etc., of the base string and wrap combinations.

Referring to Figure 9, the second bristle subassembly station 24 is shown in cross-section at the point where the corner ultrasonic assemblies engage the base strings of the first subassembly station 22. In particular, the corner ultrasonic assemblies 96, 146, 148, and 150 are juxtaposed the corners of mandrel 90. The mandrel 90 includes four inserts 152, 154, 156, and 158, which are detachably mounted on the mandrel 90. Each insert carries a detachably coupled anvil 160,

162, 164, and 166 having a shape and size similar to the anvils of the preceding station 22. A wrapping mechanism (not shown) wraps a monofilament around the mandrel 90 to form a plurality of wraps 92, in a manner similar to the wrapping that forms the wraps 28 of the first station 22.

In the first station 22, the base strings are fed via guides to the ultrasonic assemblies. In the second station 24, the subassemblies 64, 66, 68, 70, 72, 74, 76, and 80 are fed to the second station and the base strings of those subassemblies become the base strings of the second station. In other words, the wraps 92 are bonded to the base strings of the subassemblies 64, 66, 68, 70 72, 74, 76 and 80. A more detailed view is shown in Figure 10.

As seen in Figure 10, the wrap 92 extends completely around the mandrel 90 and engages the corner anvils 160 and 162. The upper surfaces of the anvils are not necessarily tapered or angled as noted with respect to the anvils of the first station 22. Also, as in the case of the first station 22, the anvils 160 and 162 are detachably mounted on inserts 152 and 154, respectively. Rather than feeding base strings through guides to engage the wraps at the ultrasonic assemblies, the station 24 feeds bristle subassemblies to the wraps.

Bristle subassembly 72, having a base string 30 and bristles 31 fed through guide 94 (Figure 2), engages the wrap 92 in a manner that the base string 30 of the bristle subassembly 72 engages the wrap 92 with the bristles 31 substantially parallel to the wrap 92. When the ultrasonic assembly 96 is energized, with the

base string 30 held between the wrap 92 and the bristles 31, which themselves are held between the end of the ultrasonic horn of assembly 96 and the base string, heat is generated which causes the wrap 92 to bond to the base string 30. Additional heating and bonding may occur between the bristles 31 and the base string 30, which tends to reinforce the previously made bond therebetween.

This process occurs at each corner. At the next corner shown in Figure 10, the bristle subassembly 76 is fed to the mandrel to engage the wrap 92. The bristle subassembly includes a base string 82 and bristles 84. Bristle subassembly 76, having a base string 82 and bristles 84 fed through a guide, engages the wrap 92 in a manner such that the base string 82 of the bristle subassembly 76 engages the wrap 92 with the bristles 84 substantially parallel to the wrap 92. When the ultrasonic assembly 150 is energized, with the base string 82 held between the wrap 92 and the bristles 84, which themselves are held between the end of the ultrasonic horn of assembly 150 and the base string 82, heat is generated which causes the wrap 92 to bond to the base string 82. Additional heating and bonding may occur between the bristles 84 and the base string 82, which tends to reinforce the previously made bond therebetween.

As seen in Figure 10, transport cables 168 and 170 move successively bound wraps upwardly along the mandrel 90 towards the mid-point bonding stations, where the wraps are bound to the bristle subassemblies fed to the mid-points along the mandrel 90. The base string 30 is slightly angled from the first bonding

process so that, in the view of Figure 11, the lower right corner of the base string 30 will engage the wrap 92 before the lower left corner. Thus, bonding will begin at the lower right corner and progress along the interface between the wrap and the lower surface of the base string 30. For this to occur, it is preferable that the upper surface of the anvil is flat, as is the lower surface of the ultrasonic horn of the ultrasonic assemblies.

Figure 12 illustrates how the mid-point ultrasonic assemblies 100, 172, 174 and 176 bond the bristle subassemblies at the midpoints of the station 24. The bristle subassemblies from the previous station 22 are fed to the second station, as herein described, at the mid-points between the corners to engage the wraps 92 between the ends of the ultrasonic assemblies 100, 172, 174, and 176 and the upper surfaces of the anvils 178, 180, 182, and 184. As ultrasonic energy is applied to the bristle subassemblies and the wraps 92, a bond is formed between the wraps and the base string of the bristle subassemblies.

Referring to Figure 13, the horn of ultrasonic assembly 100 has a flat lower surface, which engages the bristles 186 of the bristle subassembly 68. The wraps 92 engage the upper surfaces of the mid-point anvils, including anvils 178, 180, 182 and 184, so that the base strings of the mid-point bristle subassemblies can be bonded to the wraps 92. As a result of the bonding process, the wraps 92 are bonded to the surface of the base strings opposite the bristles bonded to the other side. For example, the base string 44 of bristle subassembly 68 has bristles 186 bonded thereto at one

side, and then the wraps 92 are bonded via energy supplied by ultrasonic assembly 100 to the opposite side. The bonded wraps 92 are essentially parallel to the bristles. For example, bristles 186 of bristle subassembly 68, and bristles 31 of bristle subassembly 72, are substantially parallel to the wraps 92.

As seen in Figure 14, each base string, such as base string 44, bonded at the mid-point to wraps 92 is slightly angled with respect to the wraps 92. The lower end of the horns of the ultrasonic assemblies, such as ultrasonic assembly 100, are flat, as are the upper surfaces of the anvils, such as anvil 178. Thus, when ultrasonic energy is applied to the wrap 92, base string 44 and bristle 186, frictional heat generated thereby causes the lower right corner of the base string 44 to melt first, and then the melt progresses along the lower surface of the base string and upper surface of the wrap 92 until reaching the lower right corner of the base string 44. The result for all mid-point base strings is that the wraps 92 will be connected to the mid-point base strings with the wraps being substantially parallel to the bristles, such as bristles 31 and 186.

A more detailed explanation of the slitter pairs is seen in Figure 15, which illustrate the slitter pairs of the first station 22. It will be readily apparent from the description herein and the drawings that the slitter pairs of both stations 22 and 24 operate in substantially the same way. In order to form the bristle subassemblies at the first station, the wraps must be cut in an efficient and precise manner. While any one of a variety of means may be

employed, the preferred embodiment is to use rotating slitters that are mounted in pairs around the mandrel 26. The first pair of slitters 60 and 62 is preferably rotating disks or cutter blades that are mounted on a distal end portion of a common shaft 188. The shaft 188 is rotated by a drive motor (not shown) which can be of any conventional type of electric motor controlled by any conventional control means (not shown). Preferably, the control means controls at least the speed of rotation and power on/off.

Applicators 190 and 192 apply a lubricant or coolant to the rotating cutter blades 60 and 62, respectively, to keep friction between the wraps and the blade from causing unwanted heating and deformation of the wraps. A single fluid could provide both cooling and lubricating functions. One particularly advantageous fluid is water, and one particular type of applicator is a drip applicator. Other fluids, and other cooling/lubricating means could be employed. The use of applicators is preferred, but not necessary, although when using a polymeric monofilament for the wrapping material, cooling of the blades is desirable.

A second pair of slitters is provided at the next adjacent face of the mandrel 26, as seen in Figure 15. In particular, slitters 194 and 196 are mounted on a shaft 198 which is rotated by a drive motor (not shown) and controlled by control means (not shown). Applicators 200 and 202 apply a coolant/lubricant, which helps prevent deformation of the wraps during cutting.

A third pair of slitters is provided at the next adjacent face of the mandrel 26. In particular,

slitters 204 and 206 are mounted on a shaft 208 which is rotated by a drive motor (not shown) and controlled by control means (not shown). Applicators 210 and 212 apply a coolant/lubricant, which helps prevent deformation of the wraps during cutting.

A fourth pair of slitters is provided at the next adjacent face of the mandrel 26. In particular, slitters 214 and 216 are mounted on a shaft 218 which is rotated by a drive motor (not shown) and controlled by control means (not shown). Applicators 220 and 222 apply a coolant/lubricant, which helps prevent deformation of the wraps during cutting.

With each pair of slitters, one blade is juxtaposed one of the corners of the mandrel 26 to cut the wraps on the outer side of the base string. The other blade is juxtaposed the mid-point of the face (or side) of the mandrel 26 to cut the wraps on the same side of the mid-point base string as the corresponding corner base string of the same slitter pair. At each mid-point, a cutter bed 224, 226, 228 and 230 is provided in a corresponding recess formed in the mandrel 26. Each bed includes a groove into which the corresponding mid-point slitter passes. A detailed view of a blade 60 fitting into its corresponding bed 224 is shown in Figure 16. The wrap 28 is pressed onto the upper surface of the bed 224 by the blade 60, causing a slight bow in the wrap 228.

The corner slitters would also cooperate with cutter beds that are positioned in close proximity to each corresponding corner and are thus preferably mounted on or near the inserts, near where the cable grooves are formed. Such an arrangement can be seen in

Figure 17a, in which corner slitter blade 108 fits in a cutter bed or other cooperative formation associated with the corner of the mandrel. The knife blade is beveled on one side only, and positioned with the bevel towards the bases string. The bevel acts as a plough to push the base string away and thus prevent unwanted cutting of the base string.

The scale of the drawings in Figure 15 is somewhat exaggerated in order to better illustrate the cutter blades and their corresponding drive shafts. Also, the drive shafts are described as each having a drive motor and control means. An alternative embodiment would be to have all drive shafts linked together and run by a common drive motor and common control means. The blades can be of any conventional type and are chosen depending on the type of materials to be cut. Other cutting devices can be employed, such as reciprocating blades, scissors-type blades, lasers, etc.

At the mandrel 90 of the second station 24, a similar arrangement of slitters or cutting blades is provided. Figure 17 shows a detail of how one of the slitters 106 cuts the wrap 92 after the wraps have been bonded to the base strings. In particular, the rotating cutting blade extends into a groove provided in a bed 232 to facilitate cutting of the wrap 92 at the mid-point between the corners. Once the wraps 92 are simultaneously cut by the eight slitters associated with station 24, a total of eight bristle subassemblies are formed with bristles attached to both sides of the base strings, in two parallel rows.

After the bristle subassemblies are slit and thus formed with two rows of bristles, an additional

treatment step may be employed to enhance the connection of the bristles to the base string, and also to enhance the look and feel of the bristle subassemblies. Referring to Figure 18, a bristle subassembly 76 having two rows of bristles is fed to an apparatus 234 for conditioning the bonded ends of the bristles. The apparatus includes means for guiding the bristle subassembly to an end conditioner.

In particular, the guiding means includes a first guide roller 236 which receives a bristle subassembly moving left to right from the view of Figure 18, a linear bristle guide 238 disposed tangentially to the first guide roller 236, and a second guide roller 240, which moves the conditioned bristle subassembly 76 left to right in the view of Figure 18. Drive rollers, take-up spools and other means for delivering bristle subassemblies to the apparatus 234 are not shown, but can be provided in any conventional form.

A conditioning wheel 242, disposed between the two guide rollers 236 and 240 has a circumferential groove which receives the bristles of the bristle subassembly 76, and exposes the base string to a source 244 of heated air. The source 244 could be, for example, a hot air blower. Alternatively, any other type of heating device, such as heating coils, could be employed. A cooling tank 246 which contains a cooling fluid such as water is in fluid communication with the conditioning wheel 242. This ensures that the wheel does not become heated to the point of melting or otherwise deforming the bristles. In effect, the heat from the source 244 is focused on the cut ends of the bristles where they are attached to the base string.

Figure 19 shows the cut ends of the bristles 84 and 110 where attached to the base string 82 of the bristle subassembly. As evident from the figure, the cut ends are somewhat jagged, and the predominant interface between bristle material and base string material is along one side surface of the base string. After conditioning, as seen in Figure 20, the interface forms along two adjacent surfaces, the original side surface and then some along the top surface, thus enhancing the interconnection between the base string and the bristles. Moreover, the formerly jagged ends are now smooth so that the bristles have a better feel for applications such as toothbrushes.

As seen in Figures 21 and 22, the conditioning wheel 242, rotatable about axis "a-a," has a circumferential groove 248 which receives the bristle subassembly with the base string riding on the lower surface of a first step of the groove. The bristles extend into a narrower and deeper portion of the groove, which holds the bristles in a parallel, juxtaposed position. Moreover, the heating source is directed to the first step portion of the groove, and the cooling tank 246 ensures that the wheel is not heated by the source of hot air, or other heating means, to the point that the bristles are deformed.

Other arrangements for guiding the bristles into the conditioning wheel can be envisioned. For example, and referring to Figure 23, a conditioning wheel 250 receives a bristle subassembly 252, which is fed thereto by a guide roller 254. Arrows at the top of the conditioning wheel indicate the source of hot air

impinging upon the base string region of the bristle subassembly 252 as in the previous embodiment.

As seen in Figures 24 and 25, the guide roller 254 includes two side plates 256 and 258 separated by a hub 260. A pair of guide sleeves 262 and 264 are connected to the inner surfaces of respective side plates 256 and 258. The guide sleeves define a converging pathway for guiding the bristles into the circumferential groove 266 of the conditioning wheel 250. The outer end portions of the guide sleeves extend into the groove 266 to ensure that the bristles 268 and 270 fit within the groove 266.

Several alternatives, within the scope of the invention, can be envisioned. For example, the guide sleeves do not have to be attached to the side plates, but instead could be independently supported between the conditioning wheel and the guide roller. In general, any means capable of ensuring a guided entry of the bristles into the circumferential groove of the conditioning wheel can be employed. Moreover, guiding means may be avoided altogether, depending on stiffness of the bristles and other factors, or the guiding means may be provided as a wider taper in the conditioning wheel, or by using other formations in the conditioning wheel itself.

The base strings can be monofilaments or polyfilaments. Three particularly well-suited polymeric materials, which form the monofilament, are nylon, polyester, and acetal resins. Nylon monofilaments have been used to make a wide variety of products, including brush bristles, fishing string, and tennis racket strings. One particularly well-suited

nylon material for making monofilaments is a nylon filament commercially available under the name TYNEX®, manufactured by E.I. DuPont de Nemours and Company of Wilmington, Delaware USA. One particularly useful TYNEX® product is a 6,12 nylon filament made of polyhexamethylene dodecanamide. It has a melting point of between 208 and 215ºC and has a specific gravity of 1.05-1.07, and is available commercially in many cross-sectional shapes and diameters. Other suitable materials include HYTREL®, a polyester, and DELRIN®, an acetal resin. Both HYTREL® and DELRIN® are manufactured by E.I. DuPont de Nemours and Company of Wilmington, Delaware USA and are commercially available. Chemically, an acetal is the product of a two-step reaction between an alcohol and an aldehyde. Acetal homopolymer, which became commercially available in 1960 is formed by polymerizing anhydrous formaldehyde to make a chain of oxymethylene units. Celcon® acetal copolymer from Hoechst Technical Polymers (HTP) was introduced in 1961, and is prepared by copolymerizing trioxane with a cyclic ether into more chemically resistant chains comprised of oxymethylene and oxyethylene units. The copolymer is also offered by other manufacturers.

The illustrated embodiments include base strings shown of generally square section; however, virtually any cross-sectional shape can be used for the base string, including oval, round, rectangular, and irregular shapes. The same is true for the bristles and monofilaments, which were illustrated to be of round section. Other shapes can be employed including square, rectangular, oval, square with mid section

ribs, and irregular shapes. Also, the materials may be mixed, for example by having the base string made of a monofilament material and the bristles made of either a monofilament material or a polyfilament material. Polyfilament materials may be suitable for making, for example, carpet tuft strings, as opposed to monofilaments which are suitable for making brush bristles and other products requiring rigidity. However, according to the present invention, bristle strings may be combined with tuft strings, by feeding bristle subassemblies to a wrapping station where yarn wraps are applied to a bonding station.

While a wide variety of products are envisioned for manufacture using the disclosed apparatuses and methods, one principal article for manufacture is a bristle subassembly, in which the bristle subassemblies can be cut to length and used for various brush applications. Brush applications are particularly adapted for use with monofilament wraps and monofilament base strings, both of which are thermoplastic, meaning that as they vibrate under the influence of the ultrasonic energy, the heat causes surface melting. When the energy is removed, frictional heat is immediately and rapidly lost to the adjacent sub-surface mass, causing the melted material from the base string or the wraps, or both to mechanically lock the base string and wraps together.

Similarly, a polymeric material used as either the base string or the wraps, or both, could be used to make carpet tuft strings, in which the wrapping materials is a polyfilament material of the type typically used in carpet manufacturing. Such articles

could be made with relatively minor modifications to the disclosed embodiments of machinery.

The embodiments described herein which describe bristle subassembly stations have described cables that are used to transport wraps along the mandrel. An example can be found in Figure 4, in which cables 124 and 126, which move in an endless loop so that a first run of the loop moves in one direction in a guide provided in corresponding anvils, while a second run of the loop moves in an opposite direction in a groove formed in the mandrel (enumerated 128 and 130 in Figure 4). A particularly preferred cable is described in U.S. Patent Application number 09/679,235, filed October 4, 2000, entitled "Braided Cord Splice" by Mark S. Edwards, which is incorporated herein by reference. This application describes an endless loop or belt (or cable) made by joining the ends of cord or braided individual plies, in which includes unbraiding individual plies of a portion of each end to be joined, leaving main braided bodies of cord, locating and connecting together corresponding plies from each of the ends, and pulling the connected plies back through the main braided bodies of cord, with each of the connected plies being pulled through at a different distance from the ends until the main braided bodies of cord to be joined are in close proximity and excess connected plies are protruding from the cord. Finally, the excess connected plies are removed from the cord. The result is a smooth splice with no irregularity in the cord cross-section throughout the length of the splice. The cords are preferably made of high performance materials such as para-aramids, meta-

aramids, high molecular weight linear polyolefins, polyethylene terephthalate, nylon, and similar materials.

While the embodiments described and illustrated above include a square base string, a particularly preferred embodiment includes a base string that has surface protrusions that assist in making a point of contact between the base strings and the wraps in a manner that achieves a greater efficiency in ultrasonic heating. Referring to Figure 26, a base string 300 is shown in a transverse, sectional view as being substantially square in cross-section with ribs 302, 304, 306, and 308 formed at about the mid-point between two adjacent corners. The ribs are preferably integrally formed with the main body of the base string 300 in an extruding process, or otherwise in a cost effective, expedient manner. For such processes, the preferred materials for use in forming the base string are the polymeric monofilament materials described herein with respect to the non-ribbed base strings.

The ribs provide the added advantage that a point of contact will exist between the base string and the monofilament wraps, in a manner that allows the ultrasonic energy to concentrate and initiate the melting of two objects of similar cross sectional mass, the wrap and the rib 302. Of course, the ribs or rib-like structures could be formed on base strings of other shapes, such as circular, rectangular, or substantially irregular shape. In any shape for the base string, the ribs act as "energy directors" so that the heating necessary for bonding occurs efficiently.

Further, the embodiments described herein have shown that the bristles of each bristle subassembly extend outwardly from the base string in a substantially perpendicular direction. However, other angles can be used such that the bristles extend at an angle greater or lesser than 90 degrees; the angle can be selected dependant on the use envisioned for the articles manufactured according to the present invention. For example, if brushes are to be manufactured using the subassemblies described herein, the elongated members, which would be brush bristles, can be bonded to the base string at a raked angle or at a 90 degree angle (as illustrated herein).

It is also within the scope of the present invention to vary the properties between the wraps of the first station compared to those of the second, or any successive station, so that a single bristle subassembly can include bristles having different properties. In particular, the first wraps (of the first station) can be different from the second wraps (of the second station) in at least one property, such as size, shape, composition, physical properties, and color.

The cooling source described herein, used in association with the conditioning wheel, when using a cooling fluid, can be expected to accumulate heat that should be removed by means other than ambient temperature. Although virtually any heat exchange device can be employed, one simple means would be to use a "once through" fluid, meaning that the cooling fluid flows from a source through the tank and is constantly replenished with a cool source of fluid,

such as water. Alternatively, a cooling coil can be placed in the tank to cool the fluid. However, virtually any heat removal device can be employed. Also, if the tank is large enough and ambient temperature is cool enough, it is possible for heat removal to occur at a sufficient level without additional flow through or heat removal structures.

In the embodiments described above, a bristle subassembly is combined with a monofilament at a wrapping station to produce a modified subassembly that includes a base string and two rows of elongated members. In some uses, the elongated members are bristles used to assemble brushes. In a further variation of the present invention, two unmodified subassemblies can be combined to form a modified subassembly that includes two rows of elongated members and two base strings.

Referring to Figures 27 and 28, first bristle subassembly 320 and second bristle subassembly 322 are brought together by motive forces shown by directional arrows. The arrow associated with subassembly 320 can be, for example, the reactive force of an anvil (not shown), while the arrow associated with subassembly 322 can be the reactive force of an ultrasonic horn (not shown). Each subassembly has a base string connected to a row of elongated members, and is made according to the methods described herein. Subassembly 320 has a base string 324 and a row 326 of elongated members. Both the base string and the elongated members can be made of polymeric monofilament material. Similarly, subassembly 322 includes a base string 328 and a row 330 of elongated members.

When the subassemblies 320 and 322 are brought together, as shown in Figure 28, the anvil, base string 324, rows 326 and 330 of elongated members, base string 328 and the ultrasonic horn are in substantial abutment. Ultrasonic energy is applied by energizing the ultrasonic horn to thereby deliver ultrasonic energy to the interface between the rows 326 and 330 at a level and for a time sufficient to form a bond area between the rows. The bond area represents surface melting of the elongated members at the interface, which when cooled, mechanically connects the two rows, and thus the two subassemblies, together.

The modified subassembly thus formed has two base strings between which are sandwiched two rows of elongated members. This structure results in a better capture of bristles, making it more difficult for them to separate from their respective base strings, and thus making an assembly incorporating the modified subassembly less likely to loose elongated members. Also, in some applications, the base strings connected at opposite sides form a rail-like structure that can be useful in guiding the modified subassembly into assemblies having grooves or other structures. Furthermore, in some assemblies where the subassemblies are molded in situ, such as brush heads, the base strings provide an enhanced mechanical connection to the corresponding base structure and surface for sealing capability of the mold cavity.

As in the other embodiments, the base strings and elongated members can be made of the aforementioned materials. In a particularly preferred embodiment for brush bristles, the elongated members are made of a

monofilament NYLON material, and the base strings are made of a similar material.

A structure 331 for making modified bristle subassemblies shown in Figure 28 is illustrated in Figures 29 and 30. A first guide 332 and a second guide 334 are held is spaced relation to each other by mounting on any suitable structure, such as base plate 336. Either or both guides can be provided with means for adjusting the space between them. In the illustrated embodiment, the guide 334 is provided with elongated slots and corresponding adjusting screws 338 and 340 which permit a side-to-side adjustment capability demonstrated by the double-headed directional arrow. This adjustment capability also permits the initial feeding of subassemblies 320 and 322, for example, into the structure 331.

Once fed between the guides 332 and 334, the elongated members 326 and 330, as well as the base strings 324 and 328, are brought into contact for the application of ultrasonic energy. The second guide 334 functions as an anvil and cooperates with an ultrasonic horn 342 to deliver ultrasonic energy to the interface between the abutting elongated members, as described above. The ultrasonic horn is connectable to any suitable source of ultrasonic energy, and is energized for a time, and at an energy level sufficient to cause surface melting of the elongated members.

While the illustrated embodiments show the elongated members disposed substantially normal to the base string, it may be desirable in certain applications to have the elongated members disposed at slight angles, or in chevron patterns. These

structures can be formed by changing the relative feed rates of the base string relative to the rate that the cables deliver the wraps. Depending on which moves faster, the elongated can be caused to rake forward or backwards. Combinations of forward and backward elongated members can be provided on the same base string to produce a crossed pattern. In any event, the degree of rake can be at virtually any angle but preferably "slight," which is in the range of 0-10 degrees in either the forward or rearward direction.

While the embodiments described above have illustrated cutter blades with corresponding knife beds that are substantially coplanar with the outer surface of the mandrel, and with grooves that receive the rotating blade, an alternative embodiment of knife bed is shown in Figures 31 and 32. In Figure 31, a knife bed 344 project upwardly from the surface of the mandrel. The upward projection is in degree sufficient to cause a slight bow from corner to corner for the wraps which encircle the mandrel. The outer surface of the knife bed 344 is provided with a shoulder 346 which engages the wraps at the cutting point. The corresponding knife 348 has its cutting edge extending in close proximity to the shoulder 346 and thus aids in the cutting operation. As in the previously described embodiments, the cutting operation (which may occur at different locations along the length of the mandrel to include all mid-point and corner base strings) produces a plurality of modified subassemblies. Similarly, as seen in Figure 32, the knife bed 344 and corresponding knife 348 can be used on the first station to form the

initial subassemblies that are then fed to subsequent stations to make modified subassemblies.

The various embodiments described herein can be used to form myriad products, such as brushes where the bristles are made of monofilament lengths which were cut to form the rows of elongated members. For example, Figures 33 and 34 illustrate a brush 350 according to the present invention. The brush 350 includes a body 352 having a handle portion and a head portion. The body may by made of a polymeric material of the kind that can be injection molded. A bristle array 354 is connected to the body 352 at the head portion by any suitable means. The bristle array 354 includes a plurality of segments of the subassemblies or modified subassemblies described herein.

As seen in Figure 34, the bristle array 354 includes segments 356, 358, 360, 362 and 364 arranged in five (5) parallel rows. Each segment comprises a length of the modified subassembly that includes two rows of bristles sandwiched between two base strings. However, the modified subassemblies that include two rows of bristles for one base string could also be employed. In the illustrated embodiment, the base strings are embedded in the head portion of the body, as for example, by placing the segments in a cavity and filling the cavity with a thermoplastic material. Virtually any other means can be employed for attaching the segments in, or connecting them to, the body.

The foregoing embodiments illustrate and describe subassemblies in which a first row of elongated members are attached to one side of a base string, and a second row is attached to the opposite side. In an

alternative embodiment, two rows of elongated members can be attached to the same side of the base string, which allows the opportunity to provide mixing, in the same row, elongated members of different physical characteristics, such as size, stiffness, color, material, etc. Subassemblies of this type can be formed by simply running a first subassembly through the apparatus described above, but with the first row of elongated members in contact with the wraps of the second station.

Although the invention has been described with reference to particular embodiments, it will be understood to those skilled in the art that the invention is capable of a variety of alternative embodiments within the spirit of the appended claims.